E01-004: *Extension to E93-021*
The Charged Pion Form Factor

Spokesmen:

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Hall C Experiments Planning Meeting

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Scientific Motivation

F_π has a unique place in our quest to understand hadronic structure

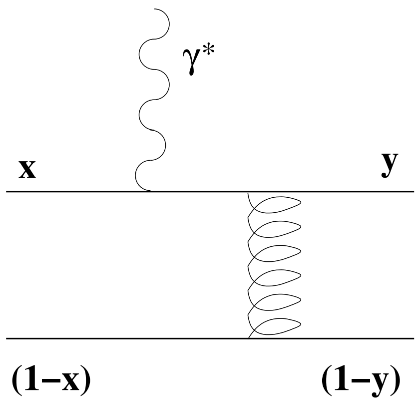
- $q\bar{q}$ valence structure of π^+ is relatively simple
- asymptotic normalization of the wave function is known from $\pi^+ \to \mu^+ \nu_\mu$ decay.

Hard Contribution:

F_π asymptotic behavior is rigorously calculable in pQCD

$$F_\pi \to \frac{8\pi\alpha_s f_\pi^2}{Q^2},$$

where f_π is the $\pi^+ \to \mu^+\nu$ decay constant.



Soft Contribution:

The interplay between the soft and hard contributions is poorly understood.

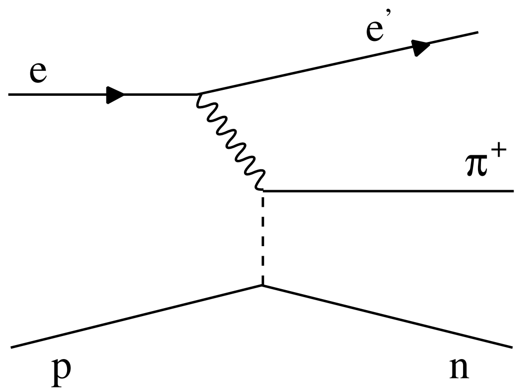
- Light Cone Sum Rule calculations indicate a large cancellation between hard and soft terms of higher twist near $Q^2 = 5\ (\mathrm{GeV/c})^2$. The total non-perturbative correction to the pQCD result could be only $\sim 30\%$ at Q^2=1 GeV/c^2.
- The success of QCD sum rule calculations, constituent quark models, and Bethe-Salpeter equation approaches can all be tested in the difficult and poorly understood gap between the “soft” and “hard” regions at intermediate Q^2.

2002 U.S. Nuclear Sciences Advisory Committee Report:

Another important issue in the physics of confinement is understanding the transition of the behavior of QCD from long distance scales (low Q^2) to short distance scales (high Q^2). The pion is one of the simplest QCD systems available for study, and the measurement of its elastic form factor is the best hope for seeing this transition experimentally.

Determination of F_π via Pion Electroproduction

To access $Q^2 > 0.3$ (GeV/c)^2, one must employ the ^{1}H$(e, e'\pi^+)n$ reaction.



- Diagram dominates for $-t < 0.2\ (\mathrm{GeV/c})^2$
- In the t-pole approximation, $\frac{d\sigma_L}{dt} \propto F_\pi^2$

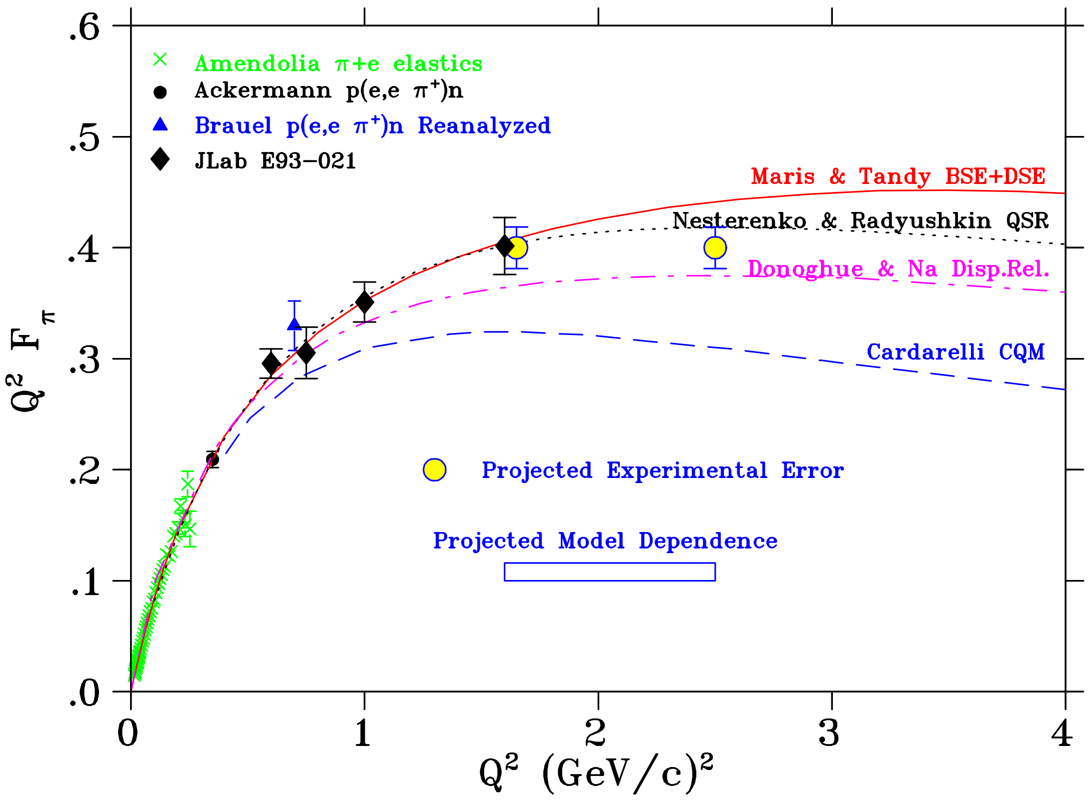
$\Rightarrow$ In the actual extraction, a model incorporating the π^+ production mechanism and the effects of the 'spectator' nucleon is used to extract F_π from σ_L.

$\Rightarrow$ π^+/π^- ratios from ^2H will be measured to test validity of t-pole dominance and the model used.

JLab 6 GeV beam now allows data to be obtained at $W = 2.2$ GeV.

$\Rightarrow$ With 4 GeV beam available for E93-021, we could only access $W = 1.95$ GeV.

- Higher W $\Rightarrow$ Closer to π^+ pole $\Rightarrow$ more reliable extraction of F_π from the σ_L data.
- Smaller model uncertainty in extracted F_π value.



$Q^2 = 2.5\ (\mathrm{GeV/c})^2$ is the highest value that can be accessed until the 12 GeV upgrade is complete.

Approved with A- Priority Scheduled from July 11-August 13, 2003.

E_e (GeV)	$\theta_{e'}$ (deg)	$E_{e'}$ (GeV)	θ_π (deg)	θ_{HMS} (deg)	p_π (GeV/c)	$\|t\|$ $(\mathrm{GeV/c})^2$	ϵ
Q^2=1.60 GeV$^2/c^2$, W=2.20 GeV							
3.772	42.43	0.809	9.76	10.50	2.907	0.096	0.339
4.702	25.55	1.739	13.47	13.47	2.907	0.096	0.600
Q^2=2.50 GeV$^2/c^2$, W=2.20 GeV							
4.210	52.15	0.768	9.21	10.50	3.334	0.208	0.267
5.248	29.76	1.806	13.69	13.69	3.334	0.208	0.552

Systematic error goal: 3.3%. Total error goal in $\mathbf{F}_\pi$: about 5%.

Requirements:

- 4 cm LH and LD targets
- HMS will be used to detect π^+ $\Rightarrow$ must operate reliably at minimum forward angle
- SOS will be used to detect e^- up to 1.737 GeV/c

$\rightarrow$ To reduce saturation effects at $Q^2 = 2.5$ (GeV/c)^2, the SOS momentum will be reduced by 4%, and its large momentum acceptance utilized to obtain the $(e, e'\pi^+)$ coincidences

$\rightarrow$ $S1 \cdot S2 \cdot Gas\ Cerenkov$ hardware trigger $\Rightarrow$ 25:1 π^- rejection efficiency

ϵ	SOS e^- rates	SOS π^- rates	HMS π^+ rates	HMS Proton rates	Random coinc. $(e^- + \pi^-/25) \cdot (\pi^+$+p)
$Q^2 = 1.6$ GeV$^2/c^2$, W=2.20 GeV					
0.600	3000 Hz	33 kHz	13 kHz	11 kHz	4.2 Hz
0.339	460 Hz	110 kHz	18 kHz	13 kHz	6.0 Hz
$Q^2 = 2.5$ GeV$^2/c^2$, W=2.20 GeV					
0.552	1000 Hz	13 kHz	5.8 kHz	5.6 kHz	0.7 Hz
0.267	220 Hz	59 kHz	11 kHz	8.2 kHz	2.0 Hz

Preliminary Run Plan

1. Establish 930 MeV/pass Linac gradient - Tune 4 pass, 3.772 GeV beam - Setup spectrometers $\Rightarrow$ 24 hours
2. ep elastic checkout $\Rightarrow$ 18 hours
   - Elastics in HMS, scan HMS from 12-30 degrees
   - HMS sieve check with thin C target, 12 degrees
   - SOS sieve check with thin C target, 40 degrees
   - ep elastic coincidences, SOS at 1.737 GeV/c, 44 deg, HMS at 2.8 GeV/c, 26 deg
3. $Q^2 = 1.6\ (\mathrm{GeV/c})^2$, $W = 2.20$ GeV, Low ϵ data taking
   - 'Central HMS' LH runs $\Rightarrow$ 17 hours
   - 'Right HMS' LH runs $\Rightarrow$ 17 hours

120 beam hours scheduled, 76 hours required

If there is time left, we could take either more statistics or LD runs.

4. Switch to 5 pass, 4.702 GeV/c beam - Setup spectrometers $\Rightarrow$ 8 hours
5. ep elastic checkout $\Rightarrow$ 12 hours
   - Elastics in HMS, scan HMS from 12-24 degrees
   - HMS sieve check with thin C target, 12 degrees
   - SOS sieve check with thin C target, 40 degrees
   - ep elastic coincidences, SOS at 1.737 GeV/c, 48 deg, HMS at 3.7 GeV/c, 21 deg
6. $Q^2 = 1.6\ (\mathrm{GeV/c})^2$, $W = 2.20$ GeV, High ϵ data taking
   - 'Central HMS' LH runs $\Rightarrow$ 6 hours
   - 'Left HMS' LH runs $\Rightarrow$ 6 hours
   - 'Right HMS' LH runs $\Rightarrow$ 6 hours

96 beam hours scheduled, 38 hours required

If there is time left, we could either take LD data, or middle ϵ $Q^2 = 2.5\ (\mathrm{GeV/c})^2$ LH.

7. Establish 1038 MeV/pass Linac gradient - Tune 4 pass, 4.210 GeV/c beam - Setup spectrometers $\Rightarrow$ 24 hours

8. ep elastic checkout $\Rightarrow$ 12 hours
   - Elastics in HMS, scan HMS from 12-28 degrees
   - HMS sieve check with thin C target, 12 degrees
   - SOS sieve check with thin C target, 40 degrees
   - ep elastic coincidences, SOS at 1.586 GeV/c, 51 deg, HMS at 3.5 GeV/c, 21 deg

9. $Q^2 = 2.5\ (\mathrm{GeV/c})^2$, $W = 2.20$ GeV, Low ϵ data taking
   - 'Central HMS' LH, LD+, LD- runs $\Rightarrow 3 \times 36 = 108$ hours
   - 'Right HMS' LH, LD+, LD- runs $\Rightarrow 3 \times 36 = 108$ hours

216 beam hours scheduled, 252 hours required (!)

10. Switch to 5 pass, 5.248 GeV beam - Setup spectrometers $\Rightarrow$ 8 hours

11. ep elastic checkout $\Rightarrow$ 12 hours
    - Elastics in HMS, scan HMS from 12-24 degrees
    - HMS sieve check with thin C target, 12 degrees
    - SOS sieve check with thin C target, 40 degrees
    - ep elastic coincidences, SOS at 1.737 GeV/c, 50 deg, HMS at 4.3 GeV/c, 18 deg

12. $Q^2 = 2.5\ (\mathrm{GeV/c})^2$, $W = 2.20$ GeV, High ϵ data taking
    - 'Central HMS' LH, LD+, LD- runs $\Rightarrow 3 \times 16 = 48$ hours
    - 'Left HMS' LH, LD+, LD- runs $\Rightarrow 3 \times 16 = 48$ hours
    - 'Right HMS' LH, LD+, LD- runs $\Rightarrow 3 \times 16 = 48$ hours

240 beam hours scheduled, 164 hours required

$\Rightarrow$ **Need to delay switch to 5 pass beam by 2.5 days.**